Errata to "An Introduction to the Physics of Particle Accelerators", 1st Ed.

Mario Conte and William W. MacKay

Chapter 1

1. p. 3, line 2: "...If more there..." should read "...If there...".
2. p. 3, line 21: "band width" should read "bandwidth".
3. Eq. (1.5) should read:

$$d\Phi_\Omega = 1000 \frac{d^4 n}{dt\, d\Omega\, (d\lambda/\lambda)}. \tag{1.5}$$

4. p. 5, 5th line from bottom: "$2V(t)$" should read "$2V_0$".
5. p. 15, Eq. (1.41) should read:

$$\frac{dr}{dp} = -\frac{2pr^2}{GMm^2}, \tag{1.41}$$

6. p. 15, Eq. (1.42) should read:

$$\alpha_p = \frac{dr}{dp} = \frac{p}{r}\frac{dr}{dp} = -\frac{2p^2 r}{GMm^2} = -2. \tag{1.42}$$

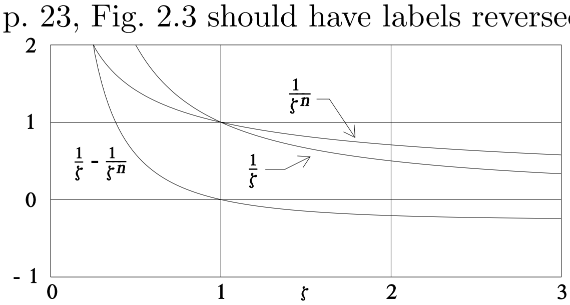
7. p. 17, in Problem **1–2**, "NdYAG" should read "Nd:YAG".

Chapter 2

8. p. 19, Eq. (2.1) should read

$$F_x = \frac{d}{dt}(\gamma m \dot{x}) = -q\beta c B_y, \quad \text{and} \tag{2.1}$$

9. p. 21, line after Eq. 2.12 should read: "...$(x/\rho)^2$ or higher, ..."
10. p. 22, caption to Fig. 2.2 should have "c) Vertical focusing..." and "d) Vertical defocusing..."
11. p. 22 first line of § 2.3 should read: "Equation (2.12)..."
12. p. 23, Fig. 2.3 should have labels reversed:



13. p. 23, Eq. (2.24) should start with $x(\theta) = \cdots$.
14. p. 23, Eq. (2.25) should start with $x'(\theta) = \cdots$.
15. p. 25, line before Eq. (2.37) should read "…when $n > 1$,"
16. p. 25, Eq. (2.38) should read:

$$\frac{d^2x}{d\theta^2} + \left[\left(1 - \frac{\delta p}{p}\right)\left(1 + \frac{1}{B_0}\frac{\partial B_y}{\partial x}x\right)\left(1 + \frac{x}{\rho}\right) - 1\right]\rho\left(1 + \frac{x}{\rho}\right) = 0, \tag{2.38}$$

17. p. 26, Eq. (2.40) should read:

$$\frac{d^2y}{d\theta^2} + \left(1 - \frac{\delta p}{p}\right) ny \left(1 + \frac{2x}{\rho}\right) \simeq \frac{d^2y}{d\theta^2} + ny = 0, \tag{2.40}$$

18. p. 29, first line of Eq. (2.56) should read:

$$\cos\frac{\sqrt{1-n}\pi}{2} - \frac{l_0}{2\rho}\sqrt{1-n}\sin\frac{\sqrt{1-n}\pi}{2} \simeq \cos\left[\left(1 + \frac{l_0}{\rho\pi}\right)\frac{\sqrt{1-n}\pi}{2}\right] \tag{2.56}$$

19. p. 29, last line of text should be "Taking into account Eq. (2.57),…"
20. p. 29, Eq. (2.63) should read:

$$\sin\mu_{\mathrm{H}} \simeq \sin\psi + \frac{l_0}{2\lambda}\cos\psi, \tag{2.63}$$

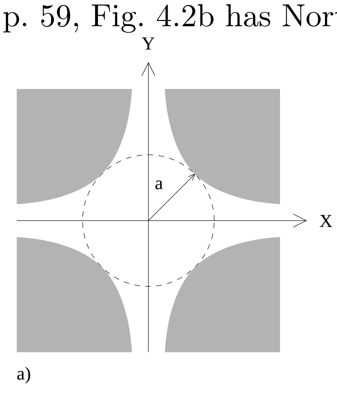
21. p. 31, last sentence should read: "But ω_{H} is just $2\pi/\tau_{\mathrm{H}} = 2\pi v/\lambda_{\mathrm{H}}$, therefore $\lambda_{\mathrm{H}} = 2\pi/\beta_{\mathrm{H}} = L/Q_{\mathrm{H}}$."

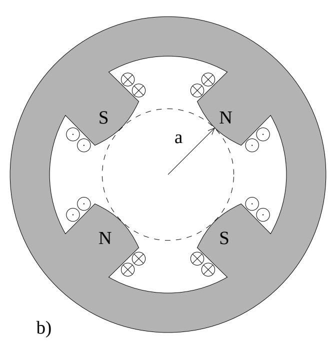
Chapter 3

None.

Chapter 4

22. p. 59, Fig. 4.2b has North and South poles reversed. Fig. 4.2 should be:





23. p. 59, Eq. (4.16) should be

$$r^2 \sin 2\theta = 2xy = a^2, \tag{4.16}$$

24. p. 64, line after Eq. (4.42) should read: "the horizontal matrix can be written as"
25. p. 66, Eq. (4.54) should be:

$$\mathbf{M}_{\mathrm{H}} = \begin{pmatrix} 1 & \rho\theta & \frac{1}{2}\rho\theta^2 \\ 0 & 1 & \theta \\ 0 & 0 & 1 \end{pmatrix}, \tag{4.54}$$

Chapter 5

26. p. 76, Eq. (5.49) should be

$$-w_0' w(s) = -\frac{w(s)}{w_0} w_0 w_0' = \sqrt{\frac{\beta(s)}{\beta_0}}\alpha_0, \tag{5.49}$$

27. p. 82, Append text to sentence containing Eq. (5.86):

$$\begin{pmatrix} \eta \\ \eta' \\ 1 \end{pmatrix} = \begin{pmatrix} C(s) & S(s) & D(s) \\ C'(s) & S'(s) & D'(s) \\ 0 & 0 & 1 \end{pmatrix} \begin{pmatrix} \eta \\ \eta' \\ 1 \end{pmatrix}, \tag{5.86}$$

where the matrix elements are evaluated for the periodic cell starting at position s.
28. p. 85, last equation in Problem **5–8** should be

$$\eta(s) = \frac{\sqrt{\beta(s)}}{2\,\sin(\pi Q_{\mathrm{H}})} \int_s^{s+L} \frac{\sqrt{\beta(\tau)}}{\rho(\tau)} \cos\left[\phi(\tau) - \phi(s) - \pi Q_{\mathrm{H}}\right] d\tau.$$

Chapter 6

29. p. 93, first line of Eq. (6.38) should be

$$\mathrm{M} = \begin{pmatrix} 1 - \frac{l_1 l_2}{f^2} + \frac{l_2}{f} & 2l_1 + l_2 - \frac{l_1^2 l_2}{f^2} \\ -\frac{l_2}{f^2} & 1 - \frac{l_1 l_2}{f^2} - \frac{l_2}{f} \end{pmatrix}$$

30. p. 96, Eq. (6.50) should be

$$\begin{aligned} M_{23} =& -\frac{\sin\mu}{\beta}\frac{1}{2}l\left(1 + \frac{l}{8f}\right)\theta_1 + \cos\mu\left(1 - \frac{l}{8f} - \frac{l^2}{32f^2}\right)\theta_1 \\ &+ \left(1 - \frac{l}{8f} - \frac{l^2}{32f^2}\right)\theta_2, \end{aligned} \tag{6.50}$$

31. p. 100, line after Eq. 6.80 should read: "By analogy with § 5.1, the block components of **U**, may be written as"

32. p. 104, replace text from Eq. (6.105) to Eq. (6.111) with:

$$\xi_{x\mathrm{N}} = -\frac{1}{4\pi Q_{\mathrm{H}}} \frac{e}{p} \oint \beta_x(s) G(s)\, ds. \tag{6.105a}$$

Actually there are two different natural chromaticities for the horizontal and vertical planes with the vertical given by

$$\xi_{y\mathrm{N}} = \frac{1}{4\pi Q_{\mathrm{V}}} \oint \beta_y(s) k_0(s)\, ds, \tag{6.105b}$$

since a horizontally focussing quadrupole defocusses in the vertical plane.

If some magnetic field imperfections give rise to a perturbation of the kind

$$B_y = \sum_{n=2}^{\infty} b_n x^n, \tag{6.106}$$

then in Eq. (6.92) $k - k_0$ must be replaced by

$$\left(-\frac{qG}{p_0} + 2\frac{q}{p_0} b_2 \eta_x \right) \frac{\Delta p}{p} + \ldots, \tag{6.107}$$

which yields the additional *residual chromaticity* in the horizontal plane:

$$\xi_{x\mathrm{R}} = \frac{1}{4\pi Q_{\mathrm{H}}} \frac{q}{p_0} \oint \beta_x(s)\, 2b_2(s) \eta_x(s)\, ds + \ldots. \tag{6.108}$$

The total chromaticity will then be

$$\xi_{x\mathrm{total}} = -\frac{1}{4\pi Q} \frac{q}{p} \oint \beta(s) \left[G(s) - 2b_2(s)\eta(s) \right] ds, \tag{6.109}$$

which may vanish, at least in principle, if

$$b_2(s) = \frac{G(s)}{2\eta(s)}. \tag{6.110}$$

Appropriately placed sextupole lenses may then compensate the natural chromaticity. For the vertical direction in a planar accelerator, the vertical residual chromaticity will be

$$\xi_{y\mathrm{R}} = -\frac{1}{2\pi Q} \frac{q}{p_0} \oint \beta_y(s) b_2(s) \eta_x(s)\, ds, \tag{6.111}$$

Chapter 7

33. p. 116, Change the 2nd line before § 7.6 to: "Fig. 7.5 shows how…"
34. p. 117, Change Eq. (7.41) to

$$\frac{dW}{dt} = -\frac{\partial H}{\partial \varphi} = \frac{qV}{2\pi h}[\sin\phi_s - \sin(\phi_s + \varphi)], \tag{7.41}$$

35. p. 118, Eq. (7.50) should read

$$t_s = \frac{2\pi h}{\omega_{\rm rf} L}\, s$$

36. p. 188, between Eqs. (7.51 and 7.52), change "electric" to "magnetic".
37. p. 118, Eq. (7.53) should read:

$$A_s \approx -\frac{p_s x}{q\rho} - \frac{p_s K}{2q}x^2 + \frac{V}{\omega_{\rm rf}} \sum_{n=-\infty}^{\infty} \delta(s - nL)\cos(\omega_{\rm rf} t + \phi_s), \tag{7.53}$$

38. p. 119, last term of Eq. (7.59) should read:

$$\cdots + \frac{qV\pi h \sin\phi_s}{L^2 \omega_{\rm rf}} s^2. \tag{7.59}$$

39. p. 119, middle line of Eq. (7.61) should read:

$$\approx -p_s + \frac{p_s K}{2}x^2 - \frac{qV}{\omega_{\rm rf}} \sum_{n=-\infty}^{\infty} \delta(s - nL)\cos\left(\phi_s + \delta\phi + \frac{2\pi h s}{L}\right) - \frac{2\pi h}{L} W$$

40. p. 121, first line should read: "The partial derivative $\partial\mathcal{F}_2/\partial s$ is actually…"
41. p. 121, middle line of Eq. (7.61) should read:

$$-\frac{qV}{\omega_{\rm rf}} \sum_{n=-\infty}^{\infty} \delta(s - nL)\cos\left[\phi_s + \varphi + \frac{2\pi h s}{L} - \frac{\omega_{\rm rf} U_s}{(p_s c)^2}(\eta_x p_\beta - p_s \eta_x' x_\beta)\right]$$

42. p. 122, Eq. (7.90) should read:

$$W_m = \frac{\Omega_s \beta^2 U_s}{\omega_{\rm rf}^2 \eta_{\rm tr}} \varphi_m. \tag{7.90}$$

43. p. 123, Eq. (7.91) should read:

$$I_L = \frac{h^2 \omega_s^2 \eta_{\rm tr}}{\beta^2 U_s} \oint \frac{\Omega_s \beta^2 U_s}{h^2 \omega_s^2 \eta_{\rm tr}} \varphi_m W_m \cos^2(\Omega_s t + \psi_0)\, dt = \pi \varphi_m W_m, \tag{7.91}$$

44. p. 125, first line of Eq. (7.103) should read:

$$A_{\mathrm{bk}} = 2\int_{-\pi}^{\pi} W\, d\phi$$

45. p. 128, last equation of Problem **7–1** should read:

$$\left(\frac{\Delta p}{p}\right) = \left[\frac{(\gamma_i^2-1)^2\gamma}{(\gamma^2-1)^2\gamma_i}\right]^{\frac{1}{4}} \left(\frac{\Delta p}{p}\right)_i,$$

Chapter 8

46. p. 134, first line should read: "..., can be calculated..."
47. p. 137, the second line after Eq. (8.48) should read "...($Q_s/Q_{\mathrm{H}} \ll 1$), ..."
48. p. 139, the last half of Eq. (8.66) should be:

$$\cdots \text{ and } \quad \langle x_\beta^2\rangle = \frac{A^2\beta_{\mathrm{H}}}{2}. \tag{8.66}$$

49. p. 142, Eq. (8.88) should read:

$$N_r = \frac{5\alpha_{\mathrm{f}}}{2\sqrt{3}}\gamma, \tag{8.88}$$

Note: In Jackson's 3rd Edition, he defines the critical frequency as in Eq. 8.84.

50. p. 144, Eq. (8.93) should read

$$\varphi = \frac{\omega_{\mathrm{rf}}\alpha_p}{U_s\Omega_s} A\sin[\Omega_s(t-t_0)], \tag{8.93}$$

51. p. 144, Eq. (8.94) should read

$$\xi = \frac{U_s\Omega_s}{\omega_{\mathrm{rf}}\alpha_p}\varphi. \tag{8.94}$$

52. p. 145, Eq. (8.97) should read

$$\Delta(A^2) \simeq -2u\oint N_\gamma\langle u_\gamma\rangle\frac{ds}{c} + \oint N_\gamma\langle u_\gamma^2\rangle\frac{ds}{c}. \tag{8.97}$$

53. p. 145, Eq. (8.98) should read

$$\left(\frac{d(A^2)}{dt}\right)_{\mathrm{QF}} \simeq \frac{\Delta(A^2)}{\tau_s} = \frac{1}{c\tau_s}\oint N_\gamma\langle U_\gamma^2\rangle ds \tag{8.98}$$

54. p. 145, Eq. (8.99) should read

$$A = A_0 e^{-t/\tau_u}, \tag{8.99}$$

55. p. 145, Eq. (8.100) should read

$$\left(\frac{d(A^2)}{dt}\right)_{\text{damping}} = -\frac{2}{\tau_u} A^2. \tag{8.100}$$

56. p. 147, Eq. (8.112) should read

$$\Delta(A^2) = \left(\frac{u_\gamma}{U_s}\right)^2 [\beta_{\mathrm{H}}\eta'^2 + 2\alpha_{\mathrm{H}}\eta\eta' + \gamma_{\mathrm{H}}\eta^2 + \beta_{\mathrm{H}}\theta_x^2 - 2(\beta_{\mathrm{H}}\eta' + \alpha_{\mathrm{H}}\eta)\theta_x]. \tag{8.112}$$

57. p. 148, The equation after Eq. (8.119) should have been numbered. This would bump all the remaining equation numbers and references in Chapter 8 by one, although for this list we keep the old numbers.
58. p. 149, Eq. (8.120) should read:

$$\sigma_x = \sqrt{\beta_{\mathrm{H}}\epsilon_{\mathrm{H}} + \left(\eta\frac{\sigma_u}{U_s}\right)^2}. \tag{8.120}$$

59. p. 150, Eq. (8.124) should read:

$$\frac{dE}{dt} = -\frac{2}{\tau_x} E, \tag{8.124}$$

60. p. 150, Eq. (8.125) should read:

$$\frac{dN}{dt} = -\frac{NE}{\tau_x \epsilon} e^{-E/2\epsilon} = -\frac{N}{\tau_{\mathrm{N}}}, \tag{8.125}$$

Chapter 9

61. p. 155, Eq. (9.24) should read:

$$\left[\frac{1}{r}\frac{\partial}{\partial r}\left(r\frac{\partial}{\partial r}\right) + \frac{1}{r^2}\frac{\partial^2}{\partial\theta^2} + \frac{\partial^2}{\partial z^2} + k^2\right] E_z = 0, \tag{9.24}$$

62. p. 156, the first line should start: "where $k^2 = \omega^2/c^2$ is. . . "
63. p. 162, last sentence of first paragraph of § 9.4 should be: "For standing waves the waveguide is usually replaced by a quasi-periodic structure, e. g., a series of drift tubes as in an Alvarez linac, or a series of resonant cavities."

64. p. 163, Eq. (9.75) should be

$$E_z = E_0 J_0 \left(\frac{X_{01}}{a} r \right), \quad \text{and} \tag{9.75}$$

65. p. 174, second line of last paragraph should start: "Arbitrarily picking $z = 0$ at one of the peaks. . ."
66. p. 175, Eq. (9.133) should read:

$$\begin{aligned} \Delta U &= \int_0^{\beta\lambda_{\rm rf}/2} qE_z(0,0,z,t)dz \\ &= \frac{qkA_{10}V}{2} I_0(0) \int_0^{\beta\lambda_{\rm rf}/2} \sin kz \sin(kz + \phi_s)\, dz \\ &= \frac{\pi q A_{10} V}{4} \cos\phi_s. \end{aligned} \tag{9.133}$$

Chapter 10

67. p. 178, Eq. (10.9) should read:

$$\frac{d^2x}{d\theta^2} + {Q_{\rm H}}^2 x = \varepsilon \cos(m\theta)\, y, \quad \text{and} \tag{10.9}$$

68. p. 178, Eq. (10.10) should read:

$$\frac{d^2y}{d\theta^2} + {Q_{\rm V}}^2 y = \varepsilon \cos(m\theta)\, x. \tag{10.10}$$

69. p. 179, Eq. (10.11) should read:

$$\frac{d^2x}{d\theta^2} + {Q_{\rm H}}^2 x = \frac{1}{2}\varepsilon_y \left[\cos(Q_{\rm V} + m)\theta + \cos(m - Q_{\rm V})\theta\right], \quad \text{and} \tag{10.11}$$

70. p. 179, Eq. (10.12) should read:

$$\frac{d^2y}{d\theta^2} + {Q_{\rm V}}^2 y = \frac{1}{2}\varepsilon_x \left[\cos(Q_{\rm H} + m)\theta + \cos(m - Q_{\rm H})\theta\right], \tag{10.12}$$

71. p. 180, Eq. (10.22) should start with

$$\begin{aligned} &\cos(m\theta)\cos^p(Q_{\rm H}\theta)\cos^q(Q_{\rm V}\theta) \\ &\qquad\qquad \cdots \end{aligned} \tag{10.22}$$

72. p. 182, three lines after Eq. (10.28) should read: "the normal sextupole and decapole are shown in Fig. 10.2b."

73. p. 185, Eq. (10.51) should read:

$$2\sin(2\phi)\frac{d\phi}{da} = -\frac{d}{da}[\cos(2\phi)] = \frac{4\delta}{\varepsilon a} + \frac{2}{a}\cos(2\phi). \tag{10.51}$$

74. p. 186, Eq. (10.58) should read:

$$\sqrt{\alpha}\frac{\varepsilon}{m}\theta = \ln\left(\frac{2\sqrt{\alpha}\sqrt{\alpha a^4 + ba^2 + c} + 2\alpha a^2 + b}{W_0}\right), \tag{10.58}$$

75. p. 186, Eq. (10.59) should read:

$$W_0 = 2\sqrt{\alpha}\sqrt{\alpha a_0^4 + ba_0^2 + c} + 2\alpha a_0^2 + b. \tag{10.59}$$

76. p. 186, Eq. (10.61) should read:

$$\sqrt{-\alpha}\frac{\varepsilon}{m}\theta = \sin^{-1}\left(\frac{\alpha a_0^2 + \frac{1}{2}b}{A_0}\right) - \sin^{-1}\left(\frac{\alpha a^2 + \frac{1}{2}b}{A_0}\right). \tag{10.61}$$

77. p. 186, Eq. (10.62) should read:

$$a^2 = \frac{A_0}{(2\delta/\varepsilon)^2 - 1}\left(\frac{2\delta}{\varepsilon} + \sin(\Omega\theta - S_0)\right), \tag{10.62}$$

78. p. 186, Eq. (10.64) should read:

$$S_0 = \sin^{-1}\left(\frac{\alpha a_0^2 + b/2}{A_0}\right). \tag{10.64}$$

79. p. 187, line before Eq. (10.73) should have: "…, and we find that a particle…"

Chapter 11

80. p. 193, Eq. (11.8) should read:

$$\frac{d^2y}{d\theta^2} + {Q_\mathrm{V}}^2 y = \frac{R^2}{\beta^2\gamma mc^2}F(y), \quad \text{or} \tag{11.8}$$

81. p. 193, before Eq. (11.10) should say: "…in a Maclaurin's series"

82. p. 193, Eq. (11.10) should read:

$$f(y) = \frac{1 - \exp\left(-\frac{y^2}{2{\sigma_\mathrm{V}}^2}\right)}{y} = \frac{y}{2{\sigma_\mathrm{V}}^2} - \sum_{n=2}^{\infty}\frac{(-1)^n}{2^n n!}\frac{y^{2n-1}}{{\sigma_\mathrm{V}}^{2n}}, \tag{11.10}$$

83. p. 194, Eq. (11.12) should read:

$$\frac{d^2y}{d\theta^2} + (Q_{\mathrm{V}} + \delta Q_{\mathrm{sc}})^2 y \simeq 0 \quad \text{with} \tag{11.12}$$

84. p. 194, Eq. (11.13) should read:

$$\delta Q_{\mathrm{sc}} = -\frac{N r_0 R^2}{2 l Q_{\mathrm{V}} {\sigma_{\mathrm{V}}}^2 \beta^2 \gamma^3} = -\frac{N r_0}{4\pi B_f \epsilon^*_{\mathrm{V,rms}} \beta \gamma^2}. \tag{11.13}$$

85. p. 194, Two lines above Eq. (11.17), the last expression should read

$$2\sigma_{\mathrm{H}}(\sigma_{\mathrm{V}} + \sigma_{\mathrm{H}})/\beta_{\mathrm{V}}.$$

86. p. 194 Eq. (11.17) should read

$$\delta Q_{\mathrm{V}} = -\frac{\beta_{\mathrm{V}} N r_0}{2\pi B_f \sigma_{\mathrm{V}}(\sigma_{\mathrm{H}} + \sigma_{\mathrm{V}})\beta^2\gamma}. \tag{11.17}$$

Note: In several places in Chapters 11 and 12, the conversion between rms and 90% emittances for a Gaussian distribution should have used the ratio $\epsilon_{90\%}/\epsilon_{\mathrm{rms}} = 4.6$ rather than 4.

87. p. 194, Eq. (11.14) and preceeding line should read:
    ...that the rms normalized emittance for a Gaussian beam is

$$\pi\epsilon^*_{\mathrm{V,rms}} = \pi\frac{(\sigma_{\mathrm{V}})^2}{\beta_{\mathrm{V}}\beta\gamma} \tag{11.14}$$

88. p. 196, just below figure caption: "where N_2 is..."
89. p. 198. To clarify the argument, the paragraph containing Eq. (11.34) should be replaced by:

    Why does this occur? The question is still open, in spite of several trials to give a satisfactory answer. Definitely, the sums of nonlinear terms give rise to overlapping resonances. In fact, bunched beams introduce azimuthal dependence with terms like $y^{2n-1}\cos 2k\theta$ which drive the resonances

$$Q_{\mathrm{V}} = \frac{2k}{2n-1+1} = \frac{k}{n}. \tag{11.34}$$

    Coupled motion should be considered in addition to the single-resonance approach. Even in the single-resonance model, the superposition of high-order resonances yields[12] stochasticity, in a way similar[13] to the transition from laminar flow to turbulence for a viscous incompressible fluid.

Chapter 12

90. p. 205, Eq. (12.5) should read:

$$\langle p_\perp^2 \rangle = \frac{p^2}{4.6}\left(\frac{\varepsilon_{\rm H}}{\beta_{\rm H}} + \frac{\varepsilon_{\rm V}}{\beta_{\rm V}}\right), \tag{12.5}$$

91. p. 205, Eq. (12.6) should read:

$$k_B T_\perp = \frac{1}{9.2} mc^2 (\beta_0\gamma_0)^2 \left(\frac{\varepsilon_{\rm H}}{\beta_{\rm H}} + \frac{\varepsilon_{\rm V}}{\beta_{\rm V}}\right). \tag{12.6}$$

92. p. 205, Eq. (12.7) should read:

$$k_B T_\perp = \frac{1}{9.2} mc^2 \beta_0\gamma_0 \left(\frac{{\varepsilon_{\rm H}}^*}{\beta_{\rm H}} + \frac{{\varepsilon_{\rm V}}^*}{\beta_{\rm V}}\right); \tag{12.7}$$

93. p. 206, Eq. (12.13) should read:

$$\frac{1}{2} k_B T_\| = \frac{1}{2} mc^2 \left\langle \left(\frac{\Delta\gamma}{\beta_0\gamma_0}\right)^2 \right\rangle = \frac{1}{2} mc^2 {\beta_0}^2 \left\langle \left(\frac{\Delta p}{p}\right)^2 \right\rangle, \tag{12.13}$$

94. p. 206, Eq. (12.14) should read:

$$\frac{3}{2} k_B T = \frac{mc^2}{2} (\beta_0\gamma_0)^2 \left[\frac{\varepsilon_{\rm H}}{4.6\beta_{\rm H}} + \frac{\varepsilon_{\rm V}}{4.6\beta_{\rm V}} + \frac{1}{{\gamma_0}^2}\left(\frac{\sigma_p}{p}\right)^2\right]. \tag{12.14}$$

95. p. 207, second sentence after Eq. (12.18) should start: "When an antiproton of velocity $v_{\bar{p}}^*$ passes an electron. . . "

96. p. 208, last part of Eq. (12.20) should read:

$$= -\frac{q^2}{2\pi\epsilon_0 v_{\bar{p}}^*}\frac{1}{r}. \tag{12.20}$$

97. p. 208, Eq. (12.22) should read:

$$\Delta W_{\bar{p}}^* = -W_e^* = -\frac{q^2 r_e c^2}{2\pi\epsilon_0 {v_{\bar{p}}^*}^2 r^2}. \tag{12.22}$$

98. p. 210, Eq. (12.41) should read:

$$\tau^* = \frac{{\beta_0}^3{\gamma_0}^3}{4\pi r_e r_p c n_e^* \ln(\Lambda)} \left[\frac{\varepsilon_{\rm H}}{4.6\beta_{\rm H}} + \frac{\varepsilon_{\rm V}}{4.6\beta_{\rm V}} + \frac{1}{{\gamma_0}^2}\left(\frac{\sigma_p}{p}\right)^2\right]^{\frac{3}{2}}. \tag{12.41}$$

99. p. 211, Eq. (12.44) should read:

$$\tau = \frac{q{\beta_0}^4{\gamma_0}^5}{4\pi r_e r_p \eta J_e \ln(\Lambda)} \left[\frac{\varepsilon_{\rm H}}{4.6\beta_{\rm H}} + \frac{\varepsilon_{\rm V}}{4.6\beta_{\rm V}} + \frac{1}{{\gamma_0}^2}\left(\frac{\sigma_p}{p}\right)^2 \right]^{\frac{3}{2}}, \tag{12.44}$$

100. p. 211, should read at bottom of page: "…from some external source of heat,…"
101. p. 212, second line from bottom should read: "…in a dispersion-free straight section,…"
102. p. 213, eighth line should have: "…result $\tau \simeq 15$s for…"
103. p. 214, end of first paragraph should have: "…the group of particles is coherent."
104. p. 218, second line of Eq. (12.76) should be:

$$-\frac{2GA_{\rm cm}}{N_s}\left[\cos\phi_{\rm cm}\sum_{k=1}^{N_s} A_k\cos\phi_k + \sin\phi_{\rm cm}\sum_{k=1}^{N_s} A_k \sin\phi_k\right]. \tag{12.76}$$

105. p. 218, first line of Eq. (12.77) should be:

$$e^{i\omega_{\rm cm}t}e^{i\phi_{\rm cm}} = \frac{1}{N_s A_{\rm cm}}\sum_{k=1}^{N_s} A_k e^{i\omega_k t}e^{i\phi_k}$$

106. p. 219, at Eq. (12.81) should have:

$$\frac{d\langle A^2\rangle}{dt} \simeq \frac{\langle A'^2\rangle - \langle A^2\rangle}{\tau_s} = -\frac{2G-G^2}{\tau_s}A_{\rm cm}^2, \tag{12.81}$$

or since $A_{\rm cm}^2 \simeq \langle A^2\rangle/N_s$,

107. p. 220, after Eq. (12.93) should have: "After substitution…"
108. p. 221, Eq. (12.96) should read

$$\frac{d\langle A^2\rangle}{dt} = -\frac{1}{NT_s}[2G - G^2(1+R_n)]\langle A^2\rangle, \tag{12.96}$$

109. p. 221, Eq. (12.98) should read

$$R_n = \frac{\langle A_n^2\rangle}{\langle A^2\rangle}N_s \tag{12.98}$$

110. p. 221, in eight line of § 12.6: "…centroid…"

Appendix A

111. p. 228, Eq. (A.5) should read:

$$\eta_{\rm tr} = \frac{1}{\gamma^2} - \alpha_p. \tag{A.5}$$

Appendix B

112. p. 231, Eqs. (B.7) should read:

$$N = |\vec{v}_+ - \vec{v}_-|\,\sigma \int \rho_+(\vec{x} - \vec{v}_+ t)\,\rho_-(\vec{x} - \vec{v}_- t)\,d^3x\,dt. \tag{B.7}$$

113. p. 231, Eqs. (B.8) should read:

$$\frac{dN}{dt} = |\vec{v}_+ - \vec{v}_-|\,f_0 N_b \sigma \int \rho_+(\vec{x} - \vec{v}_+ t)\,\rho_-(\vec{x} - \vec{v}_- t)\,d^3x\,dt. \tag{B.8}$$

114. p. 231, Eqs. (B.9) should read:

$$\mathcal{L} = |\vec{v}_+ - \vec{v}_-|\,f_0 N_b \int \rho_+(\vec{x} - \vec{v}_+ t)\,\rho_-(\vec{x} - \vec{v}_- t)\,d^3x\,dt, \tag{B.9}$$

Appendix C

115. p. 232, Eq. (C.7) should read:

$$\delta \int_{s_1}^{s_2} (\vec{P} \cdot d\vec{X} - K\,ds) = 0. \tag{C.7}$$

116. p. 233, Eq. (C.15) should read:

$$\frac{dF}{ds} = \frac{\partial F_2}{\partial s} + \sum_i \left(\frac{\partial F_2}{\partial x_i} x_i' + \frac{\partial F_2}{\partial P_i} P_i' - P_i X_i' - P_i' X_i \right), \tag{C.15}$$

Appendix D

117. p. 235, Eq. (D.4) should read:

$$\begin{pmatrix} x_2 \\ x_2' \end{pmatrix} = \begin{pmatrix} \overline{M}_{11} & \overline{M}_{12} \\ \overline{M}_{21} & 0 \end{pmatrix} \begin{pmatrix} 0 \\ x_1' \end{pmatrix} = \begin{pmatrix} \overline{M}_{12} x_1' \\ 0 \end{pmatrix}. \tag{D.4}$$

Appendix E

118. p. 238, Formula 12 in top section should read:

12. $$\vec{v} \times (\nabla \times \vec{B}) = \nabla(\vec{v} \cdot \vec{B}) - (\vec{v} \cdot \nabla)\vec{B}, \quad \text{if} \quad \vec{v} = \frac{d\vec{x}}{dt}$$

119. p. 238, 2/3 of the way down should have: "…Bessel function relations for…"